

**UNITED STATES PATENT APPLICATION FOR
HERMETIC GLASS BEAD ASSEMBLY HAVING HIGH FREQUENCY
COMPENSATION**

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"Express Mail" mailing label number: EV 386446467 US
Date of Mailing: March 1, 2004

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HERMETIC GLASS BEAD ASSEMBLY HAVING HIGH FREQUENCY COMPENSATION

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Technical Field

[0001] The present invention relates generally to microwave connectors, and more specifically to microwave connectors using dielectric inserts or beads for hermetic sealing.

Background of the Invention

[0002] As operational frequencies of microwave components and subsystems have increased, performance of electrical feed-through connections between microwave integrated circuits and coaxial connectors, waveguides, etc., has become critical. With the advent of multi-function monolithic microwave integrated circuit (MMIC) chips, impedance matching and hermeticity - not normally required at lower frequencies - have become important and tightly tolerated design criteria.

[0003] Hermeticity in microwave packages is commonly achieved by use of one or more dielectric inserts or beads. The dielectric inserts themselves are hermetic and can either be molded or fired into a sleeve, which is then soldered

into a package. If the sleeve is correctly soldered into the package, the package can be hermetically sealed. Alternatively, a dielectric insert can be molded or fired directly into the package to reduce manufacturing cost while providing greater reliability.

[0004] For high frequency microwave applications, features surrounding the dielectric insert are critical for good RF performance and such features must be tightly toleranced during manufacturing. For MMICs, coaxial connector assembly components provide electrical transition and impedance matching between a coaxial transmission line of a coaxial connector and a microstrip transmission line connected to the MMICs. To achieve impedance matching, connector components include impedance compensation. Impedance compensation can include, for example, an air dielectric between the microstrip and a coaxial connector housing, and an additional compensation gap between the dielectric insert and the air dielectric. Integrating a dielectric insert into a package and forming an air dielectric and compensation gap between the dielectric insert and a package housing becomes more difficult as components shrink in size and tolerances of features tighten.

Brief Description of the Drawings

[0005] Further details of embodiments of the present invention are explained with the help of the attached drawings in which:

[0006] **Fig. 1A** is a cross-section of a glass pellet, a sleeve, and a center conductor pin positioned on a fixture for forming a typical glass bead in accordance with the prior art;

[0007] **Fig. 1B** is a cross-section of the glass bead of **Fig. 1A** after firing;

[0008] **Fig. 2** is a cross-section of the glass bead of **Fig. 1B** mounted in a conductive insert to form a glass bead assembly in accordance with the prior art;

[0009] **Fig. 3** is a partial cross-section of an exemplary coaxial connector assembly including a conductive insert and glass bead assembly;

[0010] **Fig. 4A** is a cross-section of a glass bead in accordance with one embodiment of the present invention having a molded compensation step;

[0011] **Fig. 4B** is a cross-section of the glass bead of **Fig. 4A** after firing;

[0012] **Fig. 5A** is a cross-section of a glass pellet, a conductive insert and a center conductor pin positioned on a fixture such that a glass bead assembly in accordance with one embodiment of the present invention can be formed;

[0013] **Fig. 5B** is a cross-section of the glass bead assembly of **Fig. 5A** after firing;

[0014] **Fig. 6A** is a cross-section of a glass pellet, a conductive insert and a center conductor pin positioned on a fixture having a plug such that a glass bead assembly in accordance with an alternative embodiment of the present invention can be formed;

[0015] **Fig. 6B** is a cross-section of the glass bead assembly of **Fig. 6A** after firing;

[0016] **Fig. 7A** is a cross-section of a glass pellet, a conductive insert and a center conductor pin positioned on a fixture having a plug such that a glass bead assembly in accordance with still another embodiment of the present invention can be formed;

[0017] **Fig. 7B** is a cross-section of the glass bead assembly of **Fig. 7A** after firing;

[0018] **Fig. 8A** is a cross-section of a glass pellet, a conductive insert and a center conductor pin positioned on a fixture having a plug such that a glass bead assembly in accordance with still another embodiment of the present invention can be formed; and

[0019] **Fig. 8B** is a cross-section of the glass bead assembly of **Fig. 8A** after firing.

Detailed Description

[0020] Coaxial connector assemblies typically include an electrical feed-through connection mounted in a package housing and comprising an assembly including a dielectric insert supporting a center conductor pin, for example in shown in **Fig. 1A** and **1B**. The dielectric insert is hereinafter referred to as a glass bead; however, it will be appreciated that the dielectric insert need not comprise glass - for example, the dielectric insert can comprise a ceramic or a plastic (e.g., Teflon). Further, the dielectric insert need not be bead shaped. One of ordinary skill in the art can appreciate the myriad different materials with

which the dielectric insert can be formed and the myriad different shapes in which the dielectric insert can be formed.

[0021] Glass beads are commonly used in microwave housings that benefit from hermetic sealing. A hermetic glass bead **104** typically comprises a sleeve **140** which is soldered into a conductive insert. A traditional method of molding glass beads **104** can include a center conductor pin **116** and a sleeve **140**, both comprising Kovar, and a glass pellet **142**. Kovar is an iron based alloy comprising nickel and cobalt. The chemistry of Kovar is closely controlled so as to result in a material having a low, uniform thermal expansion characteristic substantially similar to that of glass. Further, glass will stick to a Kovar surface to form a hermetic seal. During manufacture of a typical glass bead **104**, the glass pellet **142** is positioned in the sleeve **140** and the center conductor pin **116** is positioned within the glass pellet **142**. As shown in **Fig. 1A**, a fixture **150** holds the parts in place. The fixture **150** can be made of carbon, a carbon alloy, or some other material having similar properties (e.g., a high melting temperature and low coefficient of thermal expansion). The parts are placed in a furnace and the glass is melted and flows into the final form by gravity. The finished part is shown in **Fig. 1B**. As described above, glass beads **104** can comprise materials other than glass, and need not be formed in the manner described. Further, the center conductor pin **116** and sleeve **140** can comprise materials other than Kovar, for example a material having a substantially similar thermal expansion characteristic as a material chosen as a dielectric insert. One of ordinary skill in

the art can appreciate the myriad different techniques for manufacturing a dielectric insert, such as a glass bead.

[0022] As shown in **Fig. 2**, for high frequency applications a glass bead **104** is mounted in a conductive insert **214** to form a glass bead assembly **202**. The conductive insert **214** is generally cylindrical in shape, having a proximal end and a distal end; wherein the proximal end is adjacent to a housing in which a microstrip substrate is located (as shown below in **Fig. 3**). The conductive insert **214** includes a bore varying in diameter along the length of the conductive insert **214**. A first portion of the bore receives a glass bead **104** and is sized such that a characteristic impedance of the glass bead matches a characteristic impedance of a coaxial connector. The characteristic impedance of a dielectric is given by the equation:

$$z_o = \frac{60}{\sqrt{Er}} \ln \left(\frac{D_o}{D_i} \right)$$

where Er is the relative permittivity of the dielectric (i.e., the dielectric constant), D_o is the diameter of an outer conductor (e.g., the inner surface of the bore) and D_i is the diameter of an inner conductor (e.g., the center conductor pin). In a typical microwave connector, the characteristic impedance of the coaxial connector is 50 Ω . The first portion of the bore is sized such that z_o is 50 Ω when a glass dielectric is positioned in the first portion. In other embodiments the characteristic impedance can be more or less than 50 Ω .

[0023] An entry into a package housing is preferably an air dielectric **260**. A second portion of the bore comprises the air dielectric **260**, and is sized such that the impedance of the air dielectric **260** matches the characteristic impedance of the coaxial connector (e.g., 50 Ω). Because the dielectric constant of air is lower than that of glass, the second portion of the bore is smaller in diameter than the first portion. Where the size of the coax varies – e.g., with a change in air dielectric sizes or where transitioning from a glass dielectric to an air dielectric - there is excess fringing capacitance which can cause mismatch reflection. A short section of higher impedance (inductive) line can be used to balance out the fringing capacitance and minimize the effect of the transition. By minimizing this effect, impedance matching can be optimized, allowing a signal to be efficiently coupled with circuitry of a package housing with reduced return loss. The inductive portion of the electrical feed-through, or compensation gap **262**, is positioned between the glass dielectric and air dielectric and sized such that the fringing capacitive effect is minimized. As shown, the portion of the bore forming the compensation gap **262** has a diameter slightly larger than that of the air dielectric to produce a higher impedance. The glass bead **104** located within the first portion includes a center conductor pin **116**, supported by the glass bead **104**. The center conductor pin **116** further extends through the compensation gap **262** and air dielectric **260**. The glass bead **104** allows for the formation of a hermetic seal around the center conductor pin **116**.

[0024] The air dielectric **260** should be as small as possible in order to minimize mismatch when connecting to a small high frequency microstrip

mounted in the housing (as shown in **Fig. 3**). For satisfactory high frequency performance, an appropriate transition can be incorporated into the glass bead assembly by mounting the glass bead **104** (e.g., by soldering) in the conductive insert **214** having a bore machined, cast, extruded, etc. to include the air dielectric **260** and compensation gap **262**. The conductive insert **214** typically comprises a material having a high coefficient of thermal expansion (e.g., brass or copper), thereby allowing the sleeve **140** of the glass bead to be easily and suitably soldered to the conductive insert **214**.

[0025] **Fig. 3** illustrates an exemplary coaxial connector assembly **300** in which an electrical feed-through connection **202** is used. The electrical feed-through connection **202** is mounted in a package housing **306** and positioned such that the center conductor pin **116** is in electrical communication with the microstrip substrate **308** located within the housing **306**. The housing **306** includes a cavity **324** for receiving the conductive insert **202**. To ensure a good connection between the conductive insert **202** and the housing **306**, the conductive insert **202** is fixedly attached to the housing **306**. For example, the conductive insert **202** can be soldered into the cavity **324** of the housing **306** or connected to the housing **306** by bolts. The housing further contains a second cavity **326** for associated circuitry.

[0026] The process of separately forming the glass bead and mounting the glass bead into a conductive insert machined, extruded, or otherwise formed to include an air dielectric and compensation gap can be expensive. **Figs. 4A** and **4B** illustrate one embodiment of a hermetic glass bead for use in a glass bead

assembly in accordance with the present invention which can eliminate the need for a machined compensation step, for example as in the conductive insert of **Fig. 2**. The hermetic glass bead **404** can comprise a sleeve **440** which can be soldered into a conductive insert. As described above in reference to **Fig. 1**, a method of molding glass beads **404** can include a center conductor pin **116**, a sleeve **440**, and a glass pellet **442**. The center conductor pin **116** and the sleeve **440** can comprise Kovar, in one embodiment, or alternatively some other material having similar thermal expansion coefficient characteristics as the dielectric material used. During manufacturing, the parts are positioned as shown in **Fig. 4A** on a fixture **450** in accordance with one embodiment of the present invention having a compensation step **458** positioned concentrically with the sleeve **440** and the center conductor pin **440**. The compensation step **458** comprises a substantially cylindrical portion having a diameter smaller than the inner diameter of the sleeve **440**. When fired, glass fills the gap between the compensation step and the inner surface of the sleeve **440**, as shown in **Fig. 4B**, forming a glass bead **404** having an air/glass compensation gap **466**. The glass bead **404** can be fixedly connected with a conductive insert (e.g., by soldering) to form a hermetic seal. The conductive insert can include an air dielectric formed therein, or alternatively, the air dielectric can be formed within the packaging housing. As described above, glass beads can comprise materials other than glass, and need not be formed in the manner described. Further, the compensation step can be sized such that an inductance of the resulting air/glass compensation gap can provide a desired impedance. One of ordinary skill in the

art can appreciate the myriad different techniques for manufacturing a dielectric insert, such as a glass bead.

[0027] In order to further reduce manufacturing expense, a glass bead can be molded directly into the conductive insert, as shown in **Figs. 5A** and **5B**. The glass bead is not easily molded into the conductive insert of **Fig. 2**, because a flowing glass fills the air dielectric and compensation gap during molding. In one embodiment of a glass bead assembly in accordance with the present invention, a glass bead assembly **502** can be formed by directly firing a glass pellet **542** within a conductive insert **514**. The conductive insert **514** comprises a material having a high melting temperature and preferably a low coefficient of expansion (e.g., Kovar). The conductive insert **514**, glass pellet **542** and center conductor pin **116** are positioned on a fixture **550**, and placed in a furnace. Thus, a glass bead assembly having no transition between a package housing cavity and a glass dielectric **544** is formed, as shown in **Fig. 5B**. Where no transition is formed within the glass bead assembly, transition and compensation is incorporated into a package housing, for example by machining the package housing.

[0028] A method of forming a glass to air transition without compensation in accordance with an alternative embodiment of the present invention is shown in **Figs. 6A** and **6B**. The conductive insert **614** includes a bore having a varying diameter such that a medium formed within each portion of the bore includes an impedance substantially similar to the impedance of the coaxial connector. A plug **654** is positioned to at least partially fill an air dielectric section while the

glass is molded or fired into the conductive insert **614**. The plug **654** can comprise high temperature carbon composite or some other material providing similar performance during firing. The plug **654** can be integrally formed or connected with a fixture **652**, as described above in reference to **Figs. 2** and **4**, or the plug **654** can be removably inserted into the conductive insert **614** separately from the fixture **652**. Further, the plug **654** can include a cavity for receiving a center conductor pin **116** for positioning during firing. The cavity can be formed such that the center conductor pin **116** bottoms out in the plug **654** in a very precisely toleranced hole, so that the center conductor pin **116** is concentrically positioned with respect to both the glass bead **642** and the air dielectric **660**. Alternatively, the center conductor pin **116** can be free floating so that the pin can be sheared and deburred subsequent to forming the electrical feed-through connection. As will be appreciated by one of ordinary skill in the art, there are numerous plug designs, any of which can be applied to methods and devices in accordance with the present invention.

[0029] As shown in **Fig. 6A**, during manufacturing, the center conductor pin **116** can be positioned within the plug **654**, and the plug **654** can be positioned within a portion of the conductive insert **614** in which the air dielectric **660** is to be formed. A glass pellet **642** can be positioned within the bore of the conductive insert **614**. As described above, the parts are then placed within a furnace to liquefy the glass pellet **642** such that the glass pellet **642** forms a seal around the center conductor pin **614** and adheres to the walls of the conductive insert **614**. The plug can then be removed, resulting in a glass bead assembly

602 as shown in **Fig. 6B**. The glass bead assembly **602** includes a glass dielectric **644** to air dielectric **660** transition that may result in unsatisfactory performance, particularly at higher frequencies.

[0030] A method and device in accordance with still another embodiment of the present invention is illustrated in cross-section in **Figs. 7A** and **7B**. A conductive insert **714** includes a bore varying in diameter from a distal end of the conductive insert **714** to a proximal end of the conductive insert **714**. As described above, a plug **754** is positioned within a portion of the bore for forming an air dielectric **760**. As shown in **Fig. 7A**, the plug **754** is further extended into a portion of the conductive insert **714** such that an air/glass compensation gap **762** is formed between the air dielectric **760** and the glass bead **744**. The characteristic impedance of the air/glass compensation gap **762** formed in this manner can be described by the equation:

$$z_o = \frac{60}{\sqrt{Er_{glass}}} \ln\left(\frac{D_o}{D_t}\right) + \frac{60}{\sqrt{Er_{air}}} \ln\left(\frac{D_t}{D_i}\right)$$

where Er_{glass} is the dielectric constant of the glass bead, Er_{air} is the dielectric constant of the air within the compensation gap **762**, and D_t is the diameter of the inner surface of the glass bead within the compensation gap **762**. As will be readily understood, the impedance will be greater in the compensation gap **762** than in either the glass bead **744** or the air dielectric **760**.

[0031] As shown in **Fig. 7A**, to form the compensation gap **762**, the plug **754** is either repositioned toward the distal end of the conductive insert **714** or

the plug **754** is extended in length such that the plug **754** extends from the air dielectric portion into a portion of the bore of the conductive insert **714** having a diameter sized for the glass dielectric. As described above, the center conductor pin **116** is positioned within the plug **754**, a glass pellet is positioned around the center pin conductor **116**, and the parts are positioned in a furnace. As shown in **Fig. 7B**, the glass pellet **742** liquefies and flows into the spaces not occupied by the plug **754**. As the plug **754** is removed from the glass bead assembly **702** an air dielectric **760** is formed. Further, a displaced portion of the glass bead **744** forms a high impedance inductive section (i.e., the air/glass compensation gap **762**). The impedance of this section is typically not as high as the impedance of the compensation gap of the glass bead assembly shown in **Fig. 2**. The section can be lengthened to obtain the required inductance, but the dielectric mismatch is not fully minimized. However, the assembly can provide satisfactory results at a reduced cost to manufacture.

[0032] The plug described above can be shaped, as well as sized, such that the resulting inductive section (the air/glass compensation gap) provides a desired inductance, and therefore satisfactory impedance matching between the glass dielectric and the air dielectric. For example, in some embodiments, it may be beneficial to create a slightly concave recess within the glass bead. In still other embodiments, a diameter of the portion of the plug extending into the glass bead can be smaller than the diameter of the air dielectric. The resulting air dielectric within the glass bead provides a high impedance, inductive

compensation section. One of ordinary skill in the art can appreciate the numerous variations in the shape of the high impedance inductive section.

[0033] A method and device in accordance with still another embodiment of the present invention is illustrated in **Figs. 8A** and **8B**. As described in regards to **Figs. 6A-7B**, the conductive insert **814** includes a bore varying in diameter from a distal end of the conductive insert **814** to a proximal end of the conductive insert **814**. However, the bore further includes a cavity or recess **856** extended from a portion of the bore in which a glass bead **844** is partially formed. As shown in **Fig. 8A**, during manufacturing a plug **854** is positioned within a portion of the bore to form the air dielectric **860**. A center conductor pin **116** is then positioned within the plug **854**, and a glass pellet **842** is positioned around the center pin conductor **116**. As described above, the parts are placed in a furnace. As the glass pellet **842** liquefies, glass occupies space not occupied by the plug **854**, including the cavity **856**. As the plug **854** is removed from the bearing assembly an air dielectric **860** is formed. The glass choke **858** forms a high impedance section in series with a portion of the air dielectric **864**. Because the conductive insert **814** is slightly complicated by the addition of the choke **858**, this method can be slightly more costly and provides less satisfactory results than the embodiment described above. Though the dielectric mismatch is not fully minimized, the assembly can provides satisfactory results at a reduced cost to manufacture over a typical glass bead assembly.

[0034] It should be noted that glass beads and glass bead assemblies formed in accordance with embodiments of the present invention can be used in

the coaxial connector assembly as described above in regards to **Figs. 3**. Further, glass beads and glass bead assemblies formed in accordance with embodiments of the present invention can be used in any electrical feed-through connection wherein a hermetic seal is desired, including coaxial connector assemblies having different components, packages, and methods of assembly as those described above.

[0035] The foregoing description of preferred embodiments of the present invention has been provided for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Many modifications and variations will be apparent to one of ordinary skill in the relevant arts. The embodiments were chosen and described in order to best explain the principles of the invention and its practical application, thereby enabling others skilled in the art to understand the invention for various embodiments and with various modifications that are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the claims and their equivalence.